Exhibit B

Fixed Abrasives and Selective Chemistries: Some Real Advantages for Direct STI CMP

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Numerous studies have demonstrated the outstanding planarization capabilities of Fixed Abrasives in CMP processes. [1,2,3] The ability to stop on nitride in direct STI CMP has also been demonstrated in production environments for DRAM wafers [4]. When performing direct STI CMP using selective slurries a potential difficulty is with oxide dishing during overpolish. This is an issue particularly when a wide variety of pattern densities exist, and outstanding endpointing systems are necessary to prevent excessive dishing. While Fixed Abrasives do not generally have oxide dishing effects with overpolish, they may cause erosion in isolated, low density areas. Overpolishing can produce significant erosion in 0-20% density areas while stopping on nitride in the higher density areas (30-70%). Selective chemistries have now been identified that allow Fixed Abrasive polishing to stop on nitride in low density areas while maintaining the characteristic of very low oxide dishing, even after a 100% overpolish. When using this system, MIT 964 mask wafers are shown to fully clear leaving with-in-die nitride ranges of <70 Å and trench oxide ranges <250 Å from the 10% to 100% densities and with low dishing (<100 Å) in all but the largest trench areas (1000 μm pitch or 0% density). Optimal polishing conditions, concentrations of chemicals and pHs are shown to produce nitride to oxide selectivities as high as 200:1 but since there is no mechanism for a Fixed Abrasive to remove trench oxide once the nitride has been cleared, the polish rate is effectively stopped everywhere.

Introduction

As device geometries scale down to 0.35 micron and lower, Shallow Trench Isolation (STI) becomes a necessity since it offers improved isolation between devices compared with the traditional approach of local oxidation of silicon (LOCOS)[5]. The primary goal of STI Chemical Mechanical Planarization (CMP) is to remove all the oxide over the dense active areas, and over the low density or isolated active area structures, while leaving the same residual nitride stop layer thickness across all features sizes. The residual nitride thickness determines the step height between the active surface and the trench oxide surface. Ideally, this step height would be the same across all within-die pattern densities and across the wafer.

Several approaches have been used to achieve good planarization during CMP: the use of pattern fill structures (dummy pattern) to optimize the overall pattern density [6]; the use of a reverse etch-back process to pre-planarize the wafer by reactive-ion etching, where most of the oxide from the active area is removed while protecting the trench oxide [7]; or, use of high-selectivity slurries that improve the ability to halt polishing on the nitride stop-layer [8]. These approaches each have advantages and drawbacks and can be used independently or in combination to meet planarity requirements.

Most recently, a new approach to STI CMP has been developed through the use of 3M's SlurryFree™ Fixed Abrasive Technology[9-13]. A unique combination of microreplication, coated abrasive and particle science technologies has resulted in a Fixed Abrasive capable of CMP. Small composites (i.e., 200 μm wide and 40 μm high) of abrasive (CeO_2) and resin binder are positioned on a polyester backing. The composites are precisely shaped and provide a third dimension of abrasive, as well as considerable space for chemical and by-product transport. Rather than continuously having to supply fresh abrasive to the pad via slurry, and pad conditioning, the Fixed Abrasive matrix contains all the necessary abrasive. No conditioning is required. The only chemistry necessary is pH-adjusted water to meet polish rate requirements or a selective chemical as discussed in this paper. The Fixed Abrasive is designed so that topological wafers micro-condition the abrasive composites to expose fresh mineral during polishing. A key advantage of CMP using

Fixed Abrasive over conventional methods is its selectivity to topography (often >100:1). Unless a selective chemical is used the selectivity between oxide and nitride is on the order of 1:1[1,2,3]. This provides a polishing system that rapidly planarizes, and is not susceptible to dishing upon overpolish.

Defect levels are a concern for every CMP process. Fixed Abrasive CMP defects are reported elsewhere[4,11,14]. The fact that several major semiconductor fabs are either bringing Fixed Abrasives into production or are seriously considering doing so proves that this technology is at least competitive with the best slurries available.

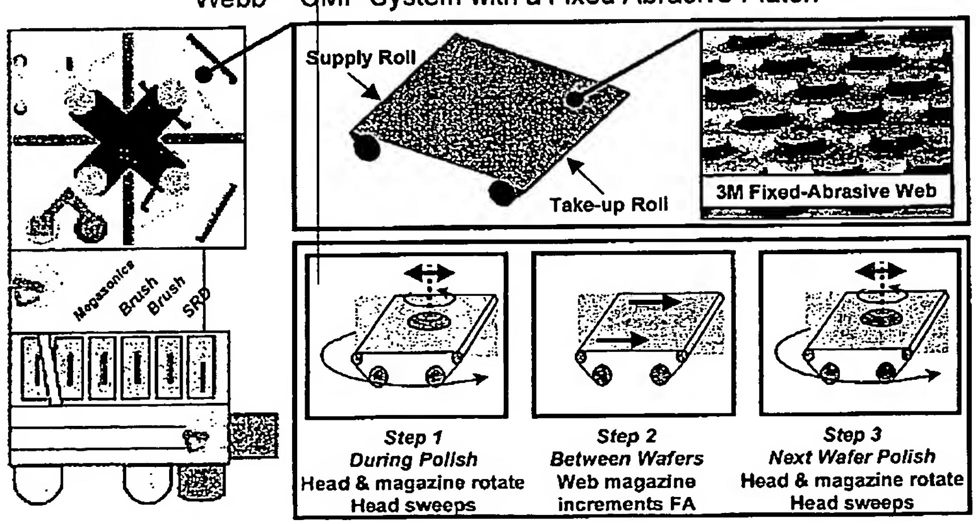
A major difficulty when performing direct STI CMP using selective slurries is oxide dishing during overpolish. Outstanding endpointing systems and excellent within-wafer nonuniformites are necessary to insure that overpolishing does not occur. While Fixed Abrasives do not generally cause oxide dishing during overpolish compared with high selectivity slurries, they may cause erosion in isolated, low density areas. Overpolishing can produce significant erosion in 0-20% active density areas while at the same time stopping on nitride in the higher density areas (30-70%).

Selective chemistries are not restricted to slurry polishing systems and may be used with Fixed Abrasives to reduce or eliminate low density erosion while maintaining the non-dishing characteristics of Fixed Abrasives. This paper presents interim work demonstrating the behavior of selective chemistries with Fixed Abrasives. The result is a polishing system that has a very large process window due to minimal dishing, with any amount of overpolish, and good nitride stopping behavior even in low density areas.

Experimental Setup

The experimental work was performed jointly by engineers from 3M and Applied Materials at the Applied Materials' R&D facility in Santa Clara, California. A 200 mm Applied Materials' Reflexion™ CMP System was used for all the MIT 964 wafer polishing. This tool may be configured for slurry or Fixed Abrasives CMP. Figure 1 shows this tool configured for Fixed Abrasives. A roll of Fixed Abrasive is loaded into each web magazine. After processing each wafer, the Fixed Abrasive is indexed a short distance across the polishing surface. For the work reported here, this distance is 3 mm. Once a certain number of wafers have been polished, each wafer thereafter sees an abrasive surface that has been used in an identical manner. Actual steady state always occurs far before the geometrical steady

Figure 1 Applied Materials' Reflexion Fixed Abrasive Webb™ CMP System with a Fixed Abrasive Platen



state – usually within 2-3 wafers. No conditioning is necessary. All wafers polished on the Reflexion used a standard 200 mm Titan™ head.

The Fixed Abrasive used is designated SWR508 and is shown in Figure 2. The abrasive pyramids are 63 µm in height and have bases approximately 125 µm. These microreplicated features wear to about a 2% bearing area during polishing.

The MIT 964 wafers are a well known test mask. Such wafers at the STI level, having a 5400 Å HDP deposition and a 4900 Å incoming step height were used. Figure 3 shows the die layout for this wafer and Figure 4 shows the locations that were used for film thickness measurements. Measurement sites include combinations of 10-90% densities and 30-500 µm pitches.

Figure 2 SWR508 Fixed Abrasive

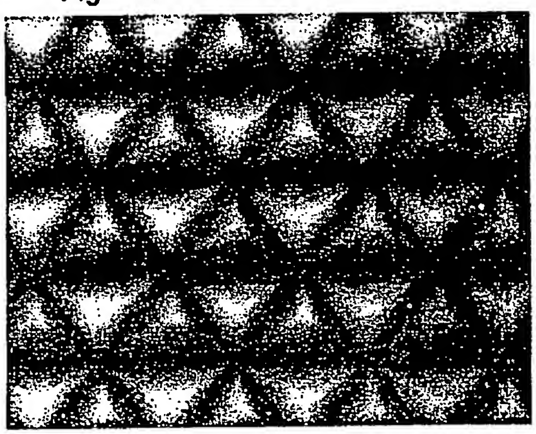
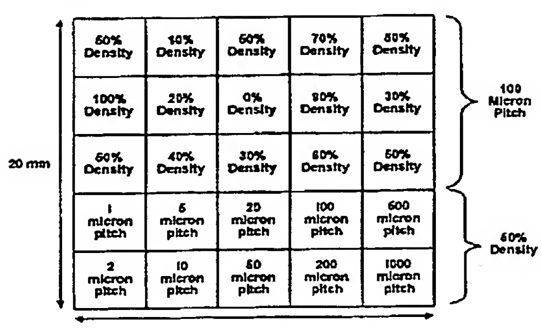


Figure 3 MIT 964 Mask Die Layout



When properly used, L-Proline has been found to be an effective selective chemical with Fixed Abrasives, [15]. To determine the optimal concentration of the selective chemistry and the best pH with which to use it, an experiment was run on an Obsidian 501 polisher. A variety of pHs and concentrations, shown in Table 1, were used to polish both blanket thermal oxide wafers (to establish oxide rate) and DRAM STI wafers that had been cleared to the nitride (to establish nitride rate). The polishing rates were used to calculate a selectivity between oxide and nitride (oxide rate/nitride rate). Whenever the rate on the

Figure 4 Measurement locations used on the MIT 964 wafers

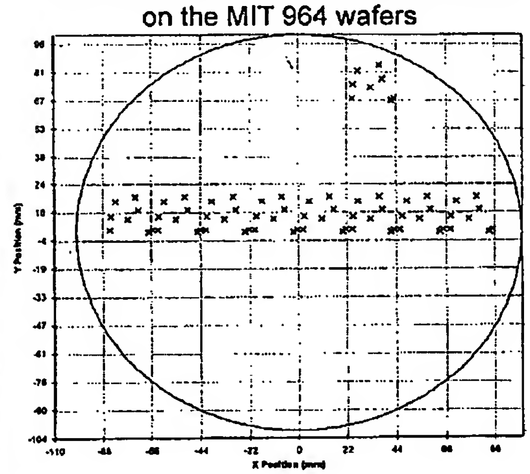
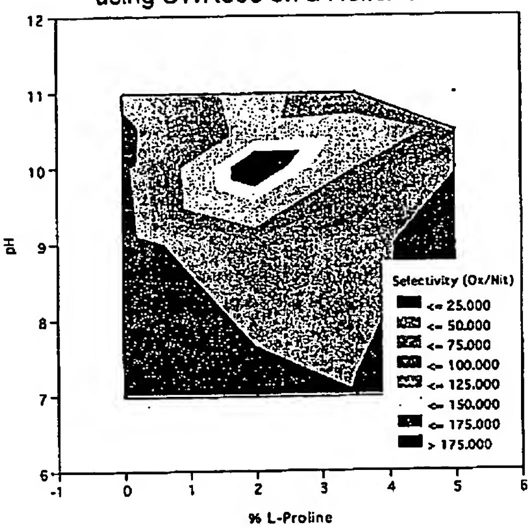


Table 1 Screening DOE to obtain approximate optimal wt. % L-Proline and pH.

% L-Proline	pH	60 s Polish: Oxide Removed	60 s Polish: Nitride Removed	Selectivity
0	7	151	25	6
0	9	159	40	4
0	10	156	11	14
0	10.5	126	10	13
0	11	342	9	38
2	7	37	13	3
2	9	72	1	72
2	10	211	1	211
2	10.5	120	1	120
2	11	127	1	127
3.5	7	23	1	23
3.5	9	38	1	38
3.5	10	101	1	101
3.5	10.5	132	1	132
3.5	11	144	3	48
5	7	2	1	2
5	9	4	1	4
5	10	27	1	27
5	10.5	88	1	88
5	11	.	7	

nitride was less than 1 Å/min a value of 1 was used. Figure 5 shows that the optimal pH and concentration of L-Proline is about 10 and 2% (by weight), respectively. Future evaluations should include 1% concentrations of L-Proline. We chose to run our tests at conditions slightly removed from this optimum so that we could make more direct comparisons with work that had been previously completed, before an optimum was known. The pH for the selective chemistry experiments was 10.5 and the L-Proline concentration used was 2.5%.

Figure 5 Optimal selectivity (Oxide/Nitride) using SWR508 on a Reflexion



Polishing MIT 964 STI Wafers

The MIT 964 wafers were polished under three different combinations of chemistry and subpad as shown in Table 2. The first was in DI water adjusted to a pH of 11.0 with KOH; the second used selective chemistry (2.5% L-Proline at a pH of 10.5) and a standard subpad (3M's P6900 - a typically stiff subpad); the third used selective chemistry on a stiffer subpad (3M's P60H50). Some of the polish times were varied to provide an opportunity to observe the effects of overpolish. The experimental design is such that comparisons may be made between subpads of different stiffness as well as with and without selective chemistry. At the time of the writing of this paper no attempt has been made to optimize the process conditions for such polishing.

Step height measurements were made on one wafer from each process condition, over a range of sites using a Tencor P22 as shown in Figure 6. All step heights are sub-100 Å except for the 50% density, 1000 μm pitch structures. Somewhere between 200-1000 μm pitch the dishing is greatly increased. A stiffer subpad reduces the step on these larger trenches by about a factor of two. Without the selective chemistry, the step heights on the more typical sized structures are all about 50 Å, but as we shall see below, a significant amount of erosion occurs in the low density areas. The use of selective chemistry adds 10-50 Å of dishing but with the benefit of almost eliminating low density erosion (discussed below).

Table 3 is a summary of the polishing results showing the with-in-die ranges (WIDR) and with-in-wafer ranges (WIWR) for pre- and post-trench oxide and nitride. Figures 7, 8, and 9 show the trench oxide ranges and Figures 10, 11, and 12 show the nitride ranges of one representative wafer from each process.

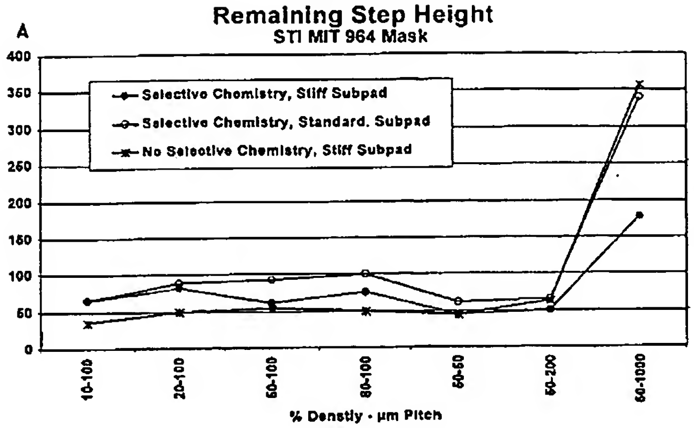
Trench oxide WIWRs are approximately the same for the different processes except that the ranges for the L-Proline on the stiffer subpad may have been slightly higher. No effort was made to improve the within-wafer uniformity on these wafers.

Table 2 Process conditions used on the MIT Wafers

Wafer #	Abrasive	Wafer Pressure	Platen/Carrier Rpm	Polish Time (sec)	Chemistry	pH	Subpad
W1	SWR505*	3.5	43/37	200	2.5% L-Proline	10.5	P6900
W2	SWR505	3.5	43/37	150	2.5% L-Proline	10.5	P6900
W3	SWR505	2.5	43/37	200	2.5% L-Proline	10.5	P6900
W4	SWR505	4.5	43/37	100	2.5% L-Proline	10.5	P6900
W5	SWR505	2.5	43/37	100	2.5% L-Proline	10.5	P6900
W6	SWR505	2.5	43/37	150	2.5% L-Proline	10.5	P6900
W7	SWR508	2.5	43/37	200	2.5% L-Proline	10.5	P60H50
W8	SWR508	2.5	43/37	200	2.5% L-Proline	10.5	P60H50
W9	SWR508	3	43/37	200	2.5% L-Proline	10.5	P60H50
W10	SWR508	3	43/37	100	DI Water only	11.0	P60H50
W11	SWR508	3	43/37	200	DI Water only	11.0	P60H50

* SWR505 is an earlier version of SWR508 that polishes the same as SWR508

Figure 6
Remaining Step Height
STI MIT 964 Mask



Wafers 5 and 6 (w5 & w6) were run at the same pressure as wafer 3 -- 2.5 psi. However, the former were preceded by a wafer (w4) run at a fairly high pressure. Since wafer 4 exhibited higher nitride and trench oxide removal it is probable that it activated the abrasive surface more than the wafers preceding wafer 3. Therefore, even though wafers 3, 5 and 6 all stopped to within 12 Å of each other on the nitride, the trench oxide removal and ranges were higher for wafers 5 and 6 due to the temporarily higher rate abrasive surface. With Fixed Abrasive polishing it may take a few wafers to stabilize after moving process conditions from more aggressive to less aggressive.

The WID ranges for both oxide and nitride are generally affected by how far we have polished into the layers. Longer polish times and higher pressures result in more removal and higher ranges. The wafers run in DI water and in the L-Proline, 6900 subpad process show that with a 100% overpolish the WID trench oxide ranges are increased by 200-300 Å. However, more erosion into the lower density areas can be seen in the DI process (Figures 7 and 10). The best WID trench oxide ranges were produced in the 2.5 psi, L-Proline, stiffer subpad process (<250 Å). The reason for this should be clear once the effect of the L-Proline on nitride removal is explained.

Looking at the DI process one can see that in the first 100 s we have cleared and polished 140 Å into the nitride (a rate of about 3300 Å/min). If an additional 100 s is applied to this process another 165 Å of nitride is removed (a rate of about 100 Å/min during the last 100 s). Clearly the rate is dramatically slowed and we know from several papers cited above, that this is due to the selectivity between topographical and planarized wafers that is characteristic of Fixed Abrasives.

L-Proline additionally appears to exhibit a very good stopping behavior on the nitride film. This stop may be overcome, somewhat, at the highest pressure

Table 3 Pre and Post Trench Oxide and Active Nitride Thickness, WIWR, and WIDR of MIT Wafers

	Trench Oxide (10-70%. 30-500 µm)						Active Nitriide (30-90%, 30-500 µm)					
	Pre			Post			Pre			Post		
Chemistry, Subpad, Polish time (s), Wafer psi	Average Thickness	WIWR	WIDR	Average Thickness	WIWR	WIDR	Average Thickness	WIWR	WIDR	Average Thickness	WIWR	WIDR
L-Proline, P6900, 200, 3.5	5434	258	48	4928	251	609	1474	59	4	1413	88	141
L-Proline, P6900, 150, 3.5	5433	255	52	4869	237	657	1472	60	5	1404	98	163
L-Proline, P6800, 200, 2.5	5414	257	49	4827	341	574	1480	58	5	1422	85	123
L-Proline, P6800, 100, 4.5	5461	250	47	4840	239	900	1484	57	5	1387	133	213
L-Proline, P6900, 100, 2.5	5429	256	52	4758	248	706	1482	58	5	1418	93	133
L-Proline, P6900, 150, 2.5	5422	253	47	4685	289	829	1490	57	5	1410	109	139
L-Proline, P60H50, 200, 2.5	5455	246	46	4984	361	215	1491	57	5	1457	64	68
L-Proline, P60H50, 200, 2.5	5439	258	51	4978	445	237	1490	57	5	1455	67	68
L-Proline, P60H50, 200, 3.0	5427	253	50	4930	362	344	1495	57	5	1449	67	92
DI Water, P60H50, 100, 3.0	5458	245	46	4787	257	517	1494	58	5	1358	128	240
DI Water, P60H50, 200, 3.0	5434	246	50	4508	268	818	1488	61	6	1193	196	405

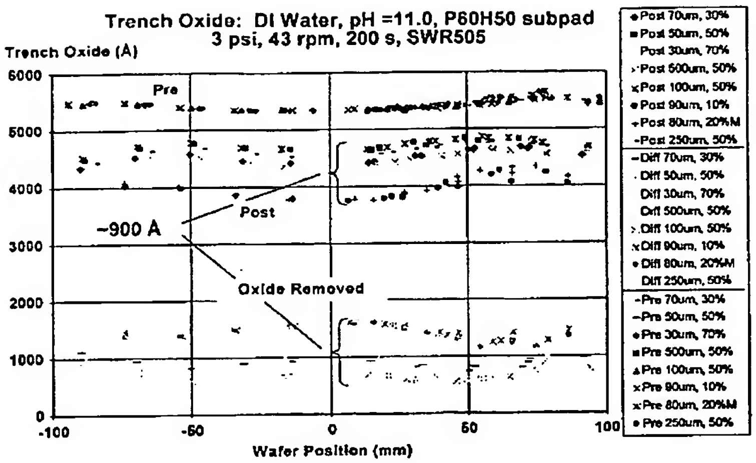


Figure 7 DI water only. High ranges mainly due to erosion in the lower density areas.

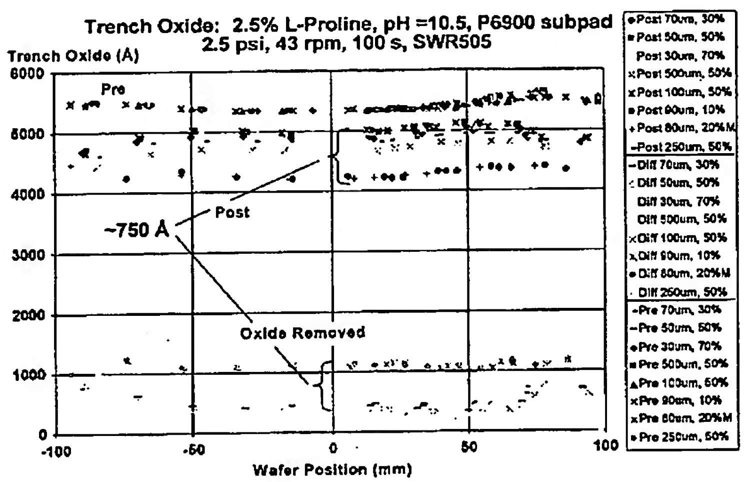


Figure 8 Selective Chemistry used. Higher ranges mainly due to erosion in the 10-20% density areas.

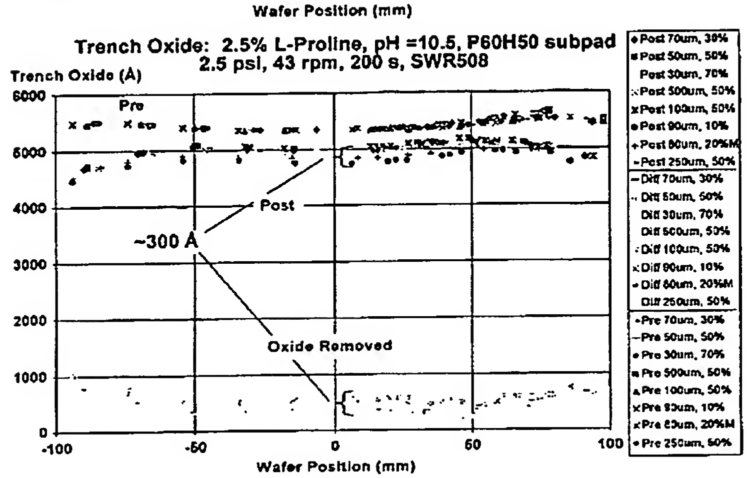


Figure 9 Selective Chemistry used along with a stiffer subpad. Better ranges due to improvement in the low density areas.

Figure 10 DI water only. High ranges mainly due to erosion in the lower density areas.

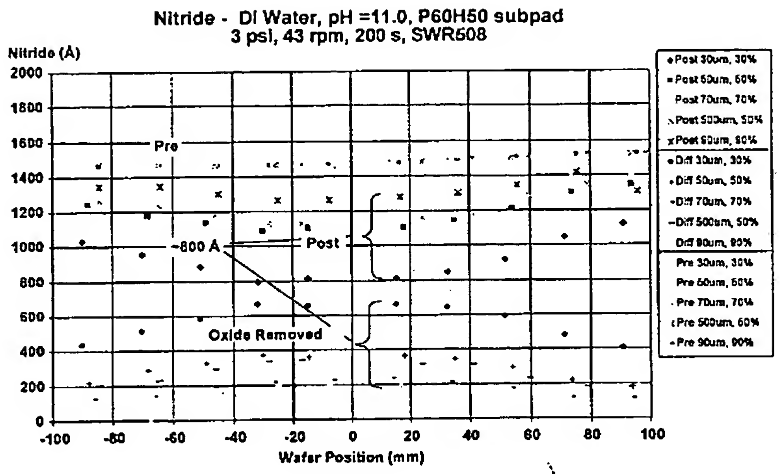


Figure 11 Selective Chemistry used. Higher ranges mainly due to erosion in the 30% density areas.

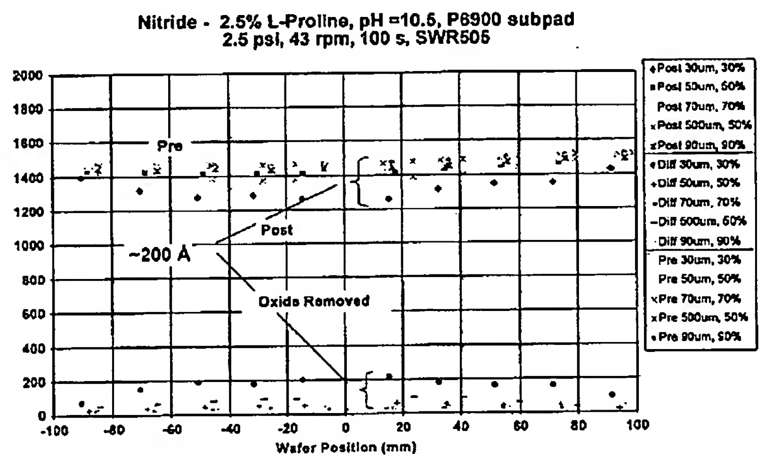
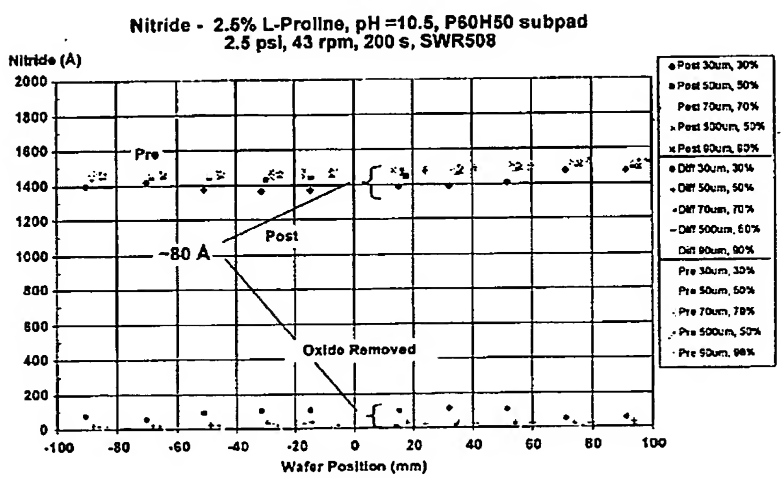


Figure 12 Selective Chemistry used along with a stiffer subpad. Better ranges due to improved stop in the low density areas.



process (4.5 psi). The WIDRs on the nitride film are otherwise nearly all <150 Å. Adding a stiffer subpad reduces this range to about 70 Å at a slight cost to the WIW trench oxide range as described above (and very likely recoverable with carrier recipe changes). The final nitride thickness is very consistent when L-Proline is used for a given subpad, independent of polish time or pressure (except for the highest - 4.5 psi - process).

Since these wafers proved to be very planar, as do most polished with Fixed Abrasive, it is understandable why the trench oxide ranges were improved when the best nitride WIDRs were achieved. Without dishing in the trench oxide, the wafer is quickly leveled at the remaining nitride height. The larger trench oxide ranges (compared to the nitride ranges) are likely a measure of larger ranges in trench depth.

Conclusions

Fixed Abrasives continue to produce outstanding planarization during CMP operations. Selective chemicals such as L-Proline can be effectively used with Fixed Abrasives. This chemical/abrasive combination can produce wafers that have very tight oxide and good nitride ranges. The process appears to have a very large process window allowing for large overpolishes with very low dishing. This may result in a reduced need for precise endpointing systems and allow for a variety of wafer types, from DRAM to Logic, to be polished. Good within-wafer uniformities can be achieved even with a very stiff subpad. The stiffer subpad significantly reduces erosion in low density areas. Selectivity between non-planarized and planarized MIT 964 wafers is at least 30:1. Selectivity between planarized oxide films and nitride films is much higher but since there is no mechanism for a Fixed Abrasives to remove trench oxide once the nitride has been cleared the polish rate is effectively stopped everywhere. The result is a robust polishing process that solves the overpolishing issues associated with slurry systems (dishing) and the erosion in isolated low density regions associated with Fixed Abrasives.

There are many obvious follow-up tests that are already underway such as using optimal L-Proline concentrations and pH, running more wafers under constant process conditions, improving WIWRs by optimizing carrier parameters, and of course, using wafers in a production environment. Defects levels are also being pursued as are a variety of STI wafer types from Logic to DRAM.

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